

WHAT IS CLAIMED IS:

1. A method for embedding a watermark signal that contains message data in a digital image represented as a two-dimensional array of pixel values, comprising the steps of:

- a) providing a dispersed message image having pixel values representative of the message data;
- b) modifying each pixel value of the dispersed message image as a function of the corresponding pixel value in the digital image; and
- c) combining the modified dispersed message image with the digital image to produce a watermarked image.

2. The method claimed in claim 1, wherein the step of providing a dispersed message image, comprises the steps of:

- a1) producing a message image representing the message data;
- a2) providing a carrier image; and
- a3) convolving the message image with the carrier image to produce the dispersed message image.

3. The method claimed in claim 2, wherein the carrier image has random phase.

4. The method claimed in claim 3, wherein the carrier image has a Fourier amplitude that models the Fourier amplitude of a specified system noise.

5. The method claimed in claim 3, wherein the carrier image has a Fourier amplitude that models the high frequencies of the Fourier amplitude of a specified system noise and contains a ramp from zero for low frequencies.

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6. The method claimed in claim 1, wherein the step of modifying each pixel of the dispersed message image comprises multiplying the pixel by a scaling factor representative of a specified system signal-dependent noise.

7. The method claimed in claim 1, further comprising the step of extracting the message data from the watermarked image.

8. The method claimed in claim 2, wherein the step of modifying each pixel of the dispersed message image comprises multiplying the pixel by a scaling factor representative of a specified system signal-dependent noise.

9. The method claimed in claim 8, further comprising the step of extracting the message image from the watermarked image by correlating the carrier image with the watermarked image.

10. The method claimed in claim 9, further comprising the steps of forming an estimate of the scaling factor for each pixel value in the dispersed message image, and dividing each pixel value of the watermarked image by the corresponding estimated scaling factor prior to extracting the message data from the watermarked image.

11. The method claimed in claim 4, wherein the specified system noise is representative of film grain noise.

12. The method claimed in claim 4, wherein the specified system noise is representative of image sensor noise.

13. The method claimed in claim 6, wherein the specified system signal-dependent noise is representative of film grain noise.

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14. The method claimed in claim 6, wherein the specified system signal-dependent noise is representative of image sensor noise.

15. The method claimed in claim 5, further comprising the step of adding low frequency noise to the dispersed message image to match the specified system noise.

16. The method claimed in claim 15, further comprising the step of extracting the message image from the watermarked image by correlating the carrier image with the watermarked image.

17. The method claimed in claim 4, further comprising the step of extracting the message image from the watermarked image by correlating the watermarked image with a second carrier image having a Fourier amplitude that matches the high frequencies of the Fourier amplitude of the specified system noise and contains a ramp from zero for low frequencies.

18. The method claimed in claim 1, wherein the digital image has been processed to remove system noise prior to embedding the watermark signal, thereby producing a watermarked image having the appearance of containing system noise.

19. The method claimed in claim 18, wherein the processing is compression and decompression.

20. A system for embedding a watermark signal that contains message data in a digital image represented as a two-dimensional array of pixel values, comprising:

a) means for providing a dispersed message image having pixel values representative of the message data;

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b) means for modifying each pixel value of the dispersed message image as a function of the corresponding pixel value in the digital image; and
c) means for combining the modified dispersed message image with the digital image to produce a watermarked image.

21. The system claimed in claim 20, wherein the means for providing a dispersed message image, comprises:

a1) means for producing a message image representing the message data;

a2) means for providing a carrier image; and

a3) means for convolving the message image with the carrier image to produce the dispersed message image.

22. The system claimed in claim 21, wherein the carrier image has random phase.

23. The system claimed in claim 22, wherein the carrier image has a Fourier amplitude that models the Fourier amplitude of a specified system noise.

24. The system claimed in claim 22 wherein the carrier image has a Fourier amplitude that models the high frequencies of the Fourier amplitude of a specified system noise and contains a ramp from zero for low frequencies.

25. The system claimed in claim 20, wherein the means for modifying each pixel of the dispersed message image comprises means for multiplying the pixel by a scaling factor representative of a specified system signal-dependent noise.

26. The system claimed in claim 20, further comprising means for extracting the message data from the watermarked image.

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27. The system claimed in claim 21, wherein the means for modifying each pixel of the dispersed message image comprises means for multiplying the pixel by a scaling factor representative of a specified system signal-dependent noise.

28. The system claimed in claim 27, further comprising means for extracting the message image from the watermarked image by correlating the carrier image with the watermarked image.

29. The system claimed in claim 28, further comprising means for forming an estimate of the scaling factor for each pixel value in the dispersed message image, and means for dividing each pixel value of the watermarked image by the corresponding estimated scaling factor prior to extracting the message image from the watermarked image.

30. The system claimed in claim 23, wherein the specified system noise is representative of film grain noise.

31. The system claimed in claim 23, wherein the specified system noise is representative of image sensor noise.

32. The system claimed in claim 25, wherein the specified system signal-dependent noise is representative of film grain noise.

33. The system claimed in claim 25, wherein the specified system signal-dependent noise is representative of image sensor noise.

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34. The system claimed in claim 24, further comprising the step of adding low frequency noise to the dispersed message image to match the specified system noise.

35. The system claimed in claim 34, further comprising the step of extracting the message image from the watermarked image by correlating the carrier image with the watermarked image.

36. The system claimed in claim 23, further comprising the step of extracting the message image from the watermarked image by correlating the watermarked image with a second carrier image having a Fourier amplitude that matches the high frequencies of the Fourier amplitude of the system noise and contains a ramp from zero for low frequencies.

37. The system claimed in claim 20, wherein the digital image has been processed to remove system noise prior to embedding the watermark signal, thereby producing a watermarked image having the appearance of containing system noise.

38. The system claimed in claim 37, wherein the processing is compression and decompression.

39. A computer program for performing the method of claim 1.

40. A watermarked image produced by the method of claim 1.

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